Article 2, Volume 5

Chapter 5

DIELECTRIC LAYER FORMING TECHNOLOGY

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1. Introduction

In an AC type PDP (Plasma Display Panel), dielectric layer is an insulating film covering the discharge electrode. Usually, the insulating film on the surface board side where are provided the maintenance electrode and the scanning electrode is called dielectric layer (Fig. 1). The role of the dielectric layer is to restrict the discharge current, by forming a capacitance between the electrodes and the discharge plasma. Although it is basically a simple glass layer, it is an important element which determines characteristics of the PDP.

Dielectric layer is mainly made of low-fusion-point glass. A transparent glass film can be obtained by baking at high temperature glass powder in the form of either paste or sheet.

2. Required characteristics

2.1 Dielectric constant

Dielectric constant is an important parameter determining discharge characteristics, but the characteristics of dielectric materials are not necessarily controlled positively, because priority is given to the characteristics of glass

material. The capacity of dielectric layer is often adjusted with its thickness.

The specific dielectric constant of dielectric materials is 11 to 14 normally. The required capacity varies depending on the construction and surface area of the electrodes or the cell design. In currently available AC type PDPs, the dielectric layer has a thickness of 30μm or so.

2.2 Transmissivity of visible light

In either a surface discharge type or a facing discharge type PDP, reflection type fluorescent surface is used in many cases. As a result, the dielectric layer is formed on the surface board side, and is requested to have a high transmissivity against visible light. To increase the transmissivity, it is necessary to well melt the material glass powder by firing it at the highest possible temperature.

Moreover, it is desirable for the dielectric layer not to have any fine air bubbles or ups and downs on the surface after the firing, as they may cause deterioration of halation or drop of contrast, by disorderly reflecting the surface light and the incident light. In such a case, care must be taken because the diffuse transmissivity is measured high, although the linear transmissivity drops.

2.3 Withstand voltage, insulation

On the surface of the dielectric (actually on the surface of a MgO film) on the discharge plasma side is accumulated wall

electric charge corresponding to the capacity of the dielectric layer. The voltage comes to as much as no less than 200 to 300V which is equivalent to the voltage applied from outside. The field intensity is no more than approximately 1×10^5 V/cm at the maximum, which is sufficiently lower than the withstand voltage of the material glass. However, in case air bubbles, etc. are included in the dielectric layer after the firing, the actual withstand voltage remarkably drops. Similarly, the insulation drops in case of poor film quality, such as a case where the melting of the material glass powder is insufficient because of shortage of firing, for example.

2.4 Flatness

On the dielectric layer is formed a thin film of MgO. The crystallinity and orientation of MgO film are known to be factors determining characteristics of PDP such as discharge voltage, spatter resistance, etc. The surface state of the dielectric layer as base layer for either electron beam vapor deposition or MgO film formed with spatter is believed to have influences on the characteristics of MgO. However, the relation between the two has not yet been clarified. As stated also in the section of transmissivity of visible light, it is desired that the MgO film formed be a transparent film with uniform crystal orientation.

2.5 Expansion coefficient

The dielectric layer has such a thickness that its expansion

coefficient cannot be ignored against the PDP substrate in the same way as the partition wall. If the expansion coefficient of the substrate is greatly different, it may lead to warping of the substrate or cracking in the process. The expansion coefficient of the substrate glass is 70 to $80\times10^{-7}/°C$. It is preferable that the expansion coefficient of the dielectric layer be found also in this range.

2.6 Softening point temperature

To form the dielectric layer transparent and flat, it is necessary to maintain the softening point temperature of the material lower than the firing temperature. Since the strain point of the glass substrate is around 550°C with soda glass and 600°C or so with high-strain-point glass, firing temperature is limited to no higher than 600°C. The softening point temperature of the dielectric material comes to no more than approximately 580°C. Usually, boro-silicated glass, etc. containing no less than 60% of PbO (lead oxide) is selected. In recent years, a proposal is made to substitute Bi_2O_3 (bismuth oxide), etc. for PbO, for the purpose of reducing the amount of lead out of consideration to environmental protection.

3. Materials

3.1 Paste

At present, the process of coating and firing paste material constitutes the main stream. Table 1 indicates characteristics of typical pastes used for screen printing. Materials with

different compositions are supplied depending on the softening point temperature selected.

When a dielectric layer is formed from a paste material, there are also cases where a double-layer construction is adopted by using a material fit for the electrode material for the lower layer and a material of good flatness for the upper layer. In that case, it is so arranged that the desired material characteristics may be demonstrated with a combination of softening point temperature and firing temperature. Those material powders are uniformly dispersed in a high-molecular binder resin to be turned into a paste. The binder resin is selected in consideration of theological properties such as dispersibility of material powder, ease of separation of binder at the time of firing, viscosity and thixotropy of paste, etc.

3.2 Green sheet

Green sheet method with simplified dielectric layer forming process is being studied as a process little subject to influences of process conditions and environments. This method consists in forming the said paste on a base film such as PET, etc. by arranging the paste in the shape of a sheet in advance. The resin material is requested to be highly flexible, to ensure easy execution of the sheet-like material.

4. Coating processes

4.1 Printing

Printing is the commonest coating process today. Screen

printing has a long history and an accumulation of know-how as a PDP manufacturing technique, and continues to be improved even now. Screen printing in PDP has been developing toward the target of forming partition walls with good accuracy. Since a dielectric is usually formed directly on the entire surface of a panel, this is not a process difficult for the screen printing technology of today. However, as mentioned in the section of required characteristics, careful material control and process control are required for dielectric layer which must be protected against air bubbles, foreign matters, etc.

Moreover, in the screen printing, selection of the thickness (μm) to be formed with a single printing is also important. If you use a screen of coarse mesh, you can shorten the working process by increasing the film thickness to be formed with a single printing. It is possible to form a dielectric layer with a thickness of 30 μm with a single printing. However, the ups and downs on the surface of the film after formation become rough, and the flatness after firing and reflow deteriorates. On the other hand, the problem of ups and downs on the surface is solved if you make the printing with a screen of fine mesh. If the mesh is fine, you have to increase the number of times of printing to obtain the prescribed thickness, and the throughput drops. It becomes important to select the screen in due consideration of the characteristics of the printing paste, the softening point temperature of the glass, etc.

4.2 Coating

The method which aims at achieving a smooth surface finish with batch formation is a new coating method using a variety of coaters. As coating processes, there are spin coat, blade coat, die coat, roll coat, etc., but it is die coat that is believed to be the process suitable for coating a thick paste of glass with a comparatively high viscosity on a large surface area.

Die coat is known as a resist coating method to semiconductor wafers. In dielectric for PDP, the basic coating structure and principle are the same, though there are some slight differences in the viscosity of material and the thickness of single coating. Fig. 2 indicates a conceptual drawing of die coat. The material paste is sent to the coating head with a pump, and coated without contact on the substrate from a slit provided in the head. The coated thickness is controlled with the feed volume from the pump and the relative speed between the head and the substrate. A mechanism is developed for absorbing waving of the substrate by making the head delicately move up and down, because large fluctuations of the gap between the substrate and the head have influences on the thickness of film.

4.3 Green sheet process

When using green sheet, the process control becomes still easier, because no thickness control is required on the user side. It is reported that the thickness of film after firing can be controlled to an accuracy of 20±0.5 μm by using a

high-performance large coater. Furthermore, because green sheet itself is easy to manufacture in clean environments, control of mixing of foreign matters in the coated film is said to be easier, compared with other thick film forming processes. A green sheet is laminated while the preheated substrate is heated and pressurized between rolls, as shown in Fig. 3. Care must be taken to avoid dragging in air bubbles or producing creases with ups and downs of the electrode, etc. formed on the substrate.

5. Drying & firing

In the case of a paste material, excess solvent is vaporized through a drying process. When forming a dielectric layer by using screen printing, it is necessary to repeat the printing-drying process until the prescribed thickness is secured. In the green sheet method, firing is made soon after lamination. The firing process has 2 major roles to play; burning out the binder resin necessary for the formation of film (removing the binder), and sufficiently melting the material glass powder. Usually, the reaction progresses at a temperature of 300 to 350°C for the removing of binder, and at a temperature of 500 to 600°C for the melting of powder. In the firing process, what is important is to control the size and density of the air bubbles produced in the film, because the former becomes a cause of defective insulation, while the latter causes obstruction to transparency. For that reason, optimization is made of the control of holding temperature, holding time, profile of

temperature increase and firing atmosphere, etc. for both removing of binder and melting of powder. Especially in the green sheet method, there is a large volume of binder resin in the film because the material is processed into a shape of sheet. This makes it necessary to also have a mechanism for efficiently discharging a large volume of outgas produced at the time of removing of binder.

6. Conclusion

Since dielectric layer is simply a flat glass layer, one may think, at a glance, that its working processes have already been fully studied. However, to take the firing process for example, there is no choice but either increase the overall length of the furnace or extend the tact time to ensure good removing of binder and melting of powder, under the current situation. Establishing compatibility among quality, mass production and cost reduction of dielectric layer is one of the major challenges. Moreover, to take environmental influences into consideration, reduction of energy consumption by the firing furnace and reduction of lead glass cannot be left untouched. It is therefore expected to promote development tracing back to material studies, such as study for realization of low-temperature processes, adoption of substitute materials with smaller environmental loads, etc.